

Appendix 11. Model Archive Summary for Suspended-Sediment Concentration at U.S. Geological Survey Site 07182390, Neosho River at Neosho Rapids, Kansas, during January 1, 2010, through December 31, 2019

This model archive summary summarizes the suspended-sediment concentration (SSC) model developed to compute hourly or daily SSC during January 1, 2010, through December 31, 2019. This model is used concomitantly with other models during this period to calculate concentrations when other explanatory variables are not available for the purposes of load and concentration model calculations. The methods used follow U.S. Geological Survey (USGS) guidance as referenced in relevant Office of Surface Water/Office of Water Quality Technical Memoranda and USGS Techniques and Methods, book 3, chapter C4 (Rasmussen and others, 2009; U.S. Geological Survey, 2016), and other standard USGS methods (Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010).

Site and Model Information

Site number: 07182390

Site name: Neosho River at Neosho Rapids, Kansas

Location: Lat 38°22'05", long 96°00'00" referenced to North American Datum of 1927, in SW 1/4 NW 1/4 sec.29, T.19 S., R.13 E., Lyon County, Kans., hydrologic unit 11070201, on right upstream side of bridge, 0.75 mile west of the intersection of Kansas Highway 130 and South Street at Neosho Rapids, and at mile 370.7.

Equipment: Sutron Satlink data logger/transmitter (DCP) and bubble gage installed in 3x5x2-foot (ft) steel shelter located on right upstream side of bridge. Bubble gage equipment includes Design Analysis H-350XL pressure transducer and H-355 gas purge system. An FTS radar stage sensor was installed on April 4, 2017, after the orifice was buried by sediment. The radar sensor is located on the downstream side of the bridge approximately 200 ft west of the gage house. This radar sensor serves as the primary recording gage, there are currently no plans to reinstall the orifice. The reference gage is a wire-weight gage (installed by National Weather Service) mounted to the downstream side of the bridge rail. Check-bar elevation is 36.543 ft.

Date model was developed: January 16, 2020

Model calibration data period: August 12, 2009, through March 14, 2019

Model Data

All data were collected using USGS protocols (Wagner and others, 2006; Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010; U.S. Geological Survey, variously dated) and are

stored in the National Water Information System (NWIS) database (<https://doi.org/10.5066/F7P55KJN>; U.S. Geological Survey, 2020). Explanatory variables were evaluated individually and in combination. Potential explanatory variables included streamflow, water temperature, specific conductance, and turbidity. Seasonal components (sine and cosine variables) were also evaluated as explanatory variables.

The regression model is based on 56 concomitant values of discretely collected SSC samples and continuously measured streamflow during August 12, 2009, through March 14, 2019. Discrete samples were collected over a range of streamflows. No samples had concentrations below laboratory detection limits. Identification of potential outliers included any values that exceeded the Cook's D test (Cook, 1977) and any point for which the studentized residual was greater than 3 or less than -3 . One sample in this dataset was deemed an outlier and was removed from the model calibration dataset. The sample removed from this dataset was collected on May 28, 2015, during backwater conditions, resulting in a large amount of streamflow data to be estimated.

Suspended-Sediment Sampling Details

Discrete samples were collected from the downstream side of the bridge or instream within 150 ft of the bridge using equal-width-increment, multiple vertical, single vertical, or grab-dip methods following U.S. Geological Survey (2006) and Rasmussen and others (2014). Discrete samples were collected on a semifixed to event-based schedule ranging from 4 to 10 samples per year with a Federal Interagency Sedimentation Project U.S. DH-48, DH-77 TM, DH-81, DH-95, and D-95, with a Teflon bottle, cap, and nozzle, D-96, with a plastic bag, Teflon collar, and nozzle depth-integrating sampler or a grab sample depending on sample location. Samples were analyzed for SSC, loss on ignition, and occasionally five-point grain size by the USGS Sediment Laboratory in Iowa City, Iowa.

Continuous Data

Streamflow was measured using a nonsubmersible pressure transducer during July 30, 2009, through April 4, 2017. Streamflow was measured using an FTS radar stage sensor during April 4, 2017, through March 14, 2019 (U.S. Geological Survey, 2018). The continuous streamflow data used were time interpolated values from the continuous time series. If the continuous data were not available, the sample was not included in the dataset. The range of continuous streamflow data (in cubic feet per second) was as follows: maximum 34,100; minimum 12.9; mean 1,160; median 271.

Model Development

Ordinary least squares regression analysis was done using R programming language (R Core Team, 2019) to relate discretely collected SSC to streamflow and other continuously measured data. The distribution of residuals was examined for normality and plots of residuals

(the difference between the measured and model calculated values) compared to model calculated SSC were examined for homoscedasticity (departures from zero did not change substantially over the range of model calculated values). Previously published explanatory variables were also strongly considered for continuity however, the best explanatory variable(s) was ultimately selected.

When the SSC and turbidity model could not be applied the streamflow model was selected instead as a good predictor of logarithm base 10 (\log_{10}) (SSC) based on residual plots, relatively high coefficient of determination (R^2), and relatively low model standard percentage error (MSPE).

Model Summary

Summary of final SSC regression analysis at site 07182390:
SSC-based model:

$$\text{Log}_{10}(\text{SSC}) = 0.799 \times \text{Log}_{10}(Q) - 0.0546$$

where

SSC = suspended-sediment concentration, in milligrams per liter, and
Q = streamflow, in cubic feet per second.

The log-transformed model may be retransformed to the original units to calculate SSC directly. A bias is introduced in the calculated constituent during retransformation and may be corrected using the Duan's bias correction factor (BCF; Duan, 1983). The calculated BCF is 1.43 for this model and the formula for the retransformed model accounting for BCF is as follows:

$$\text{SSC} = 1.26 \times Q^{0.799}$$

Previously Published Model

$$\text{Log}_{10}(\text{SSC}) = 0.700 \times \text{Log}_{10}(Q) + 0.32$$

Model author: Foster (2014)

Model data period: June 17, 2009, through September 27, 2012

Model Statistics, Data, and Plots

Model

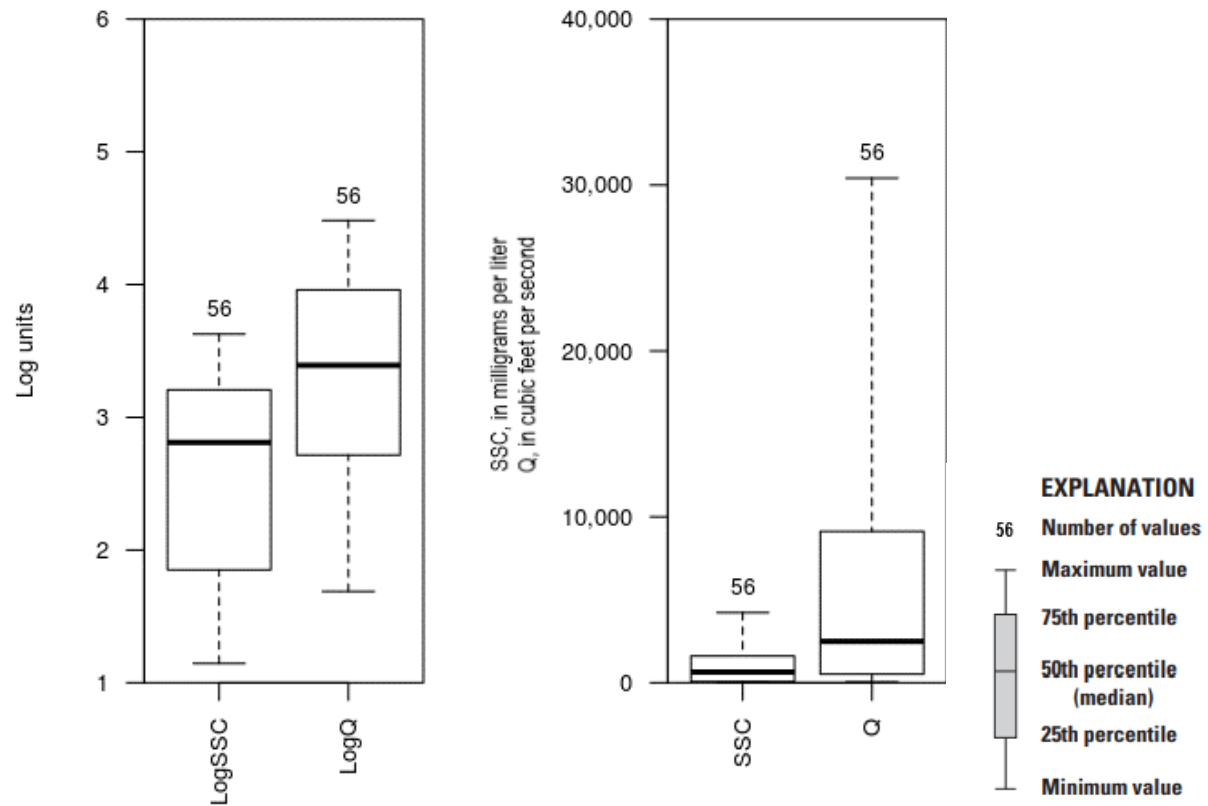
$$\text{Log}(\text{SSC}) = + 0.799 * \text{Log}(Q) - 0.0546$$

Variable Summary Statistics

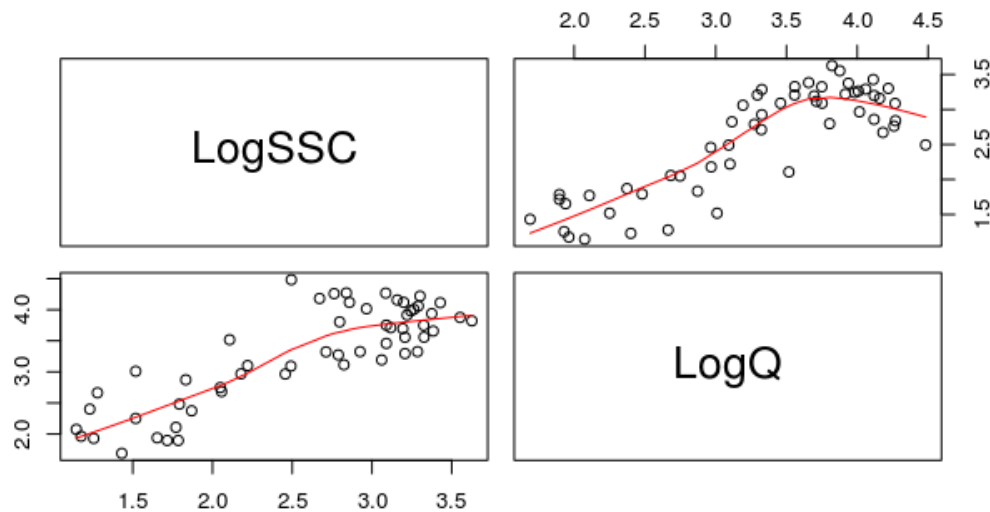
	LogSSC	SSC	LogQ	Q
Minimum	1.15	14	1.69	48.8
1st Quartile	1.85	71	2.72	521.0
Median	2.81	647	3.39	2490.0

Mean	2.58	953	3.29	5570.0
3d Quartile	3.21	1610	3.96	9130.0
Maximum	3.63	4230	4.48	30400.0

Box Plots



Exploratory Plots



Basic Model Statistics

Number of Observations	56
Standard error (RMSE)	0.407
Average Model standard percentage error (MSPE)	108
Coefficient of determination (R^2)	0.705
Adjusted Coefficient of Determination (Adj. R^2)	0.699
Bias Correction Factor (BCF)	1.43

Explanatory Variables

	Coefficients	Standard Error	t value	Pr(> t)
(Intercept)	-0.0546	0.2380	-0.23	8.19e-01
LogQ	0.7990	0.0704	11.40	6.29e-16

Correlation Matrix

	Intercept	E.vars
Intercept	1.000	-0.974
E.vars	-0.974	1.000

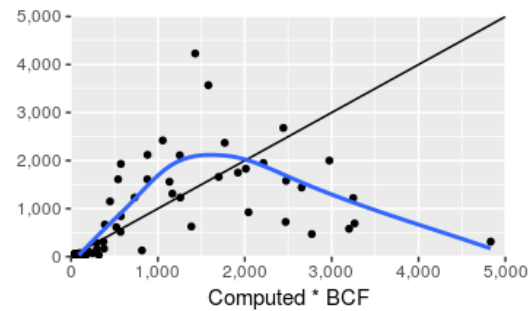
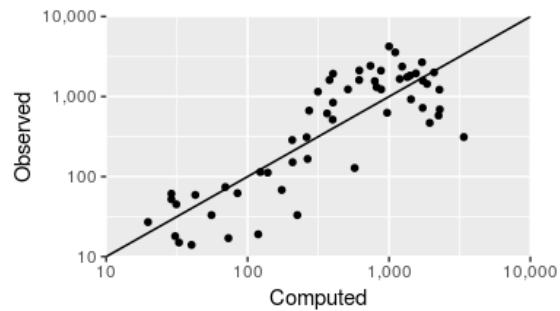
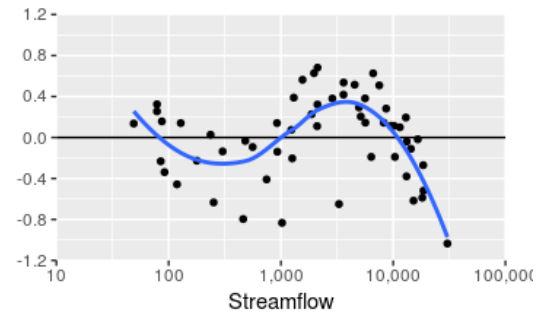
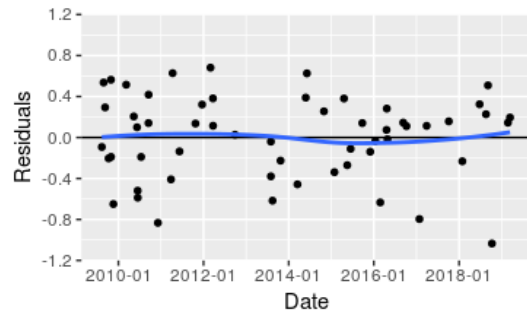
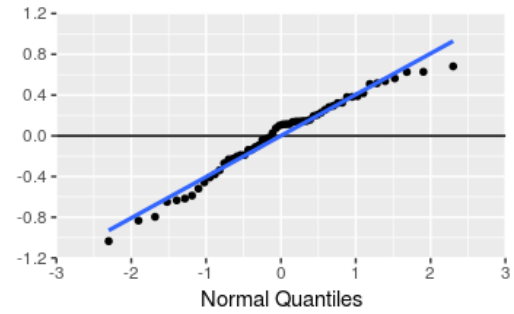
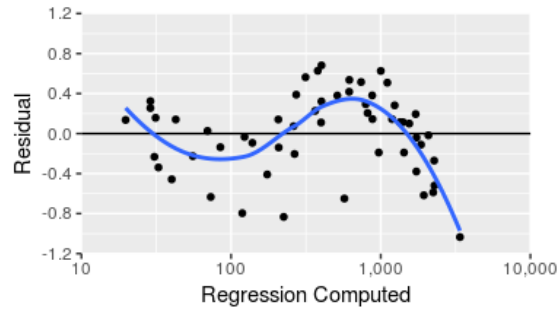
Outlier Test Criteria

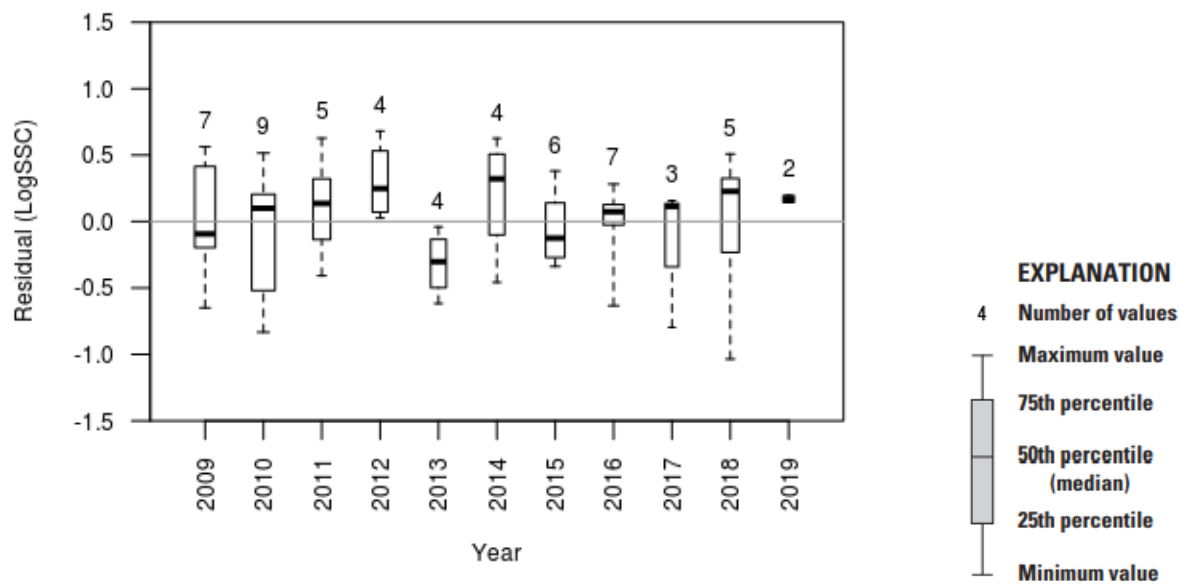
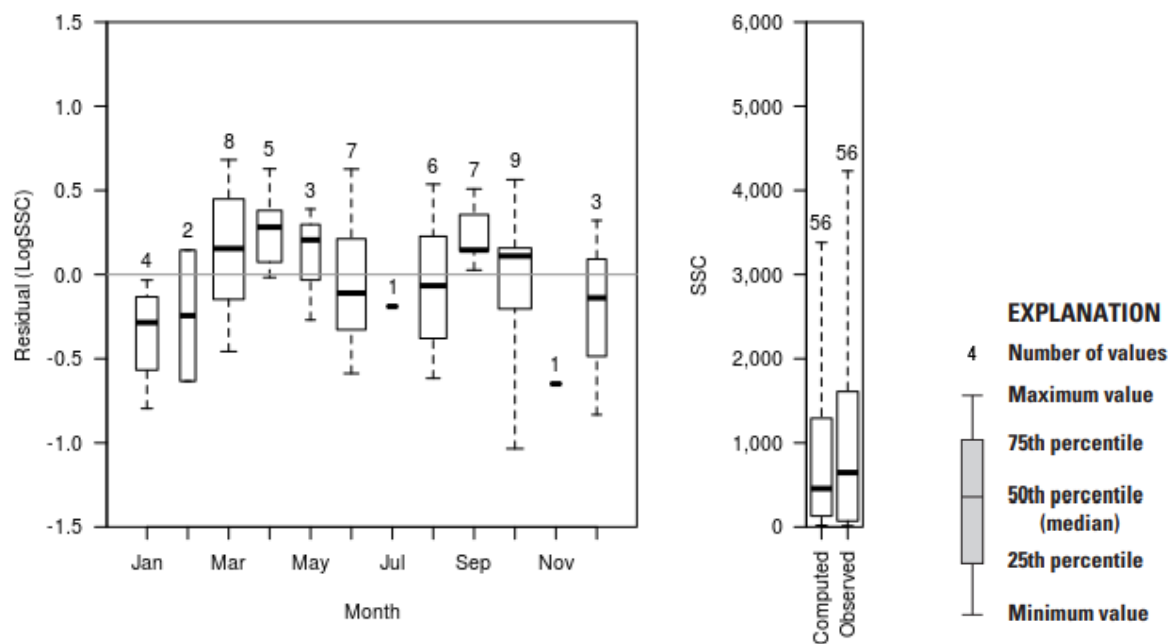
Leverage	Cook's D	DFFITS
0.107	0.194	0.378

Flagged Observations

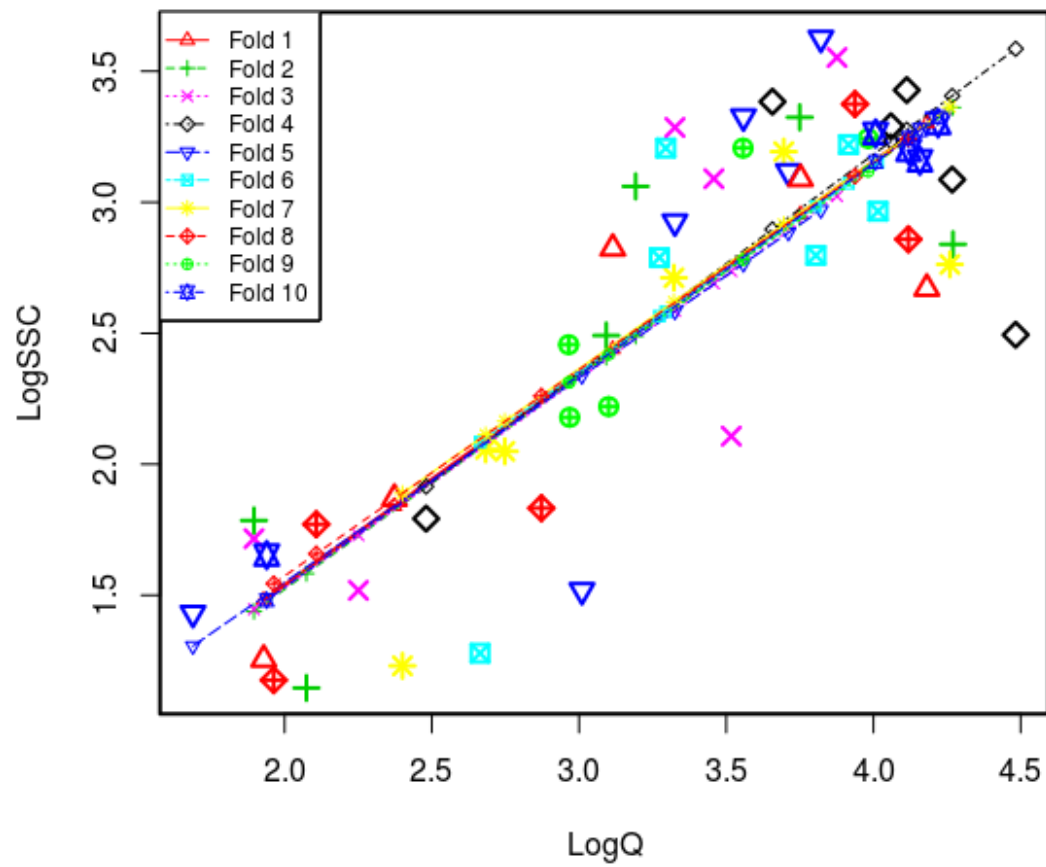
	LogSSC	Estimate	Residual	Standard Residual	Studentized Residual	Leverage	Cook's D	DFFITS
10/10/2018 11:50	2.49	3.53	-1.03		-2.62		-2.78	0.0604
							0.221	-0.705

Statistical Plots

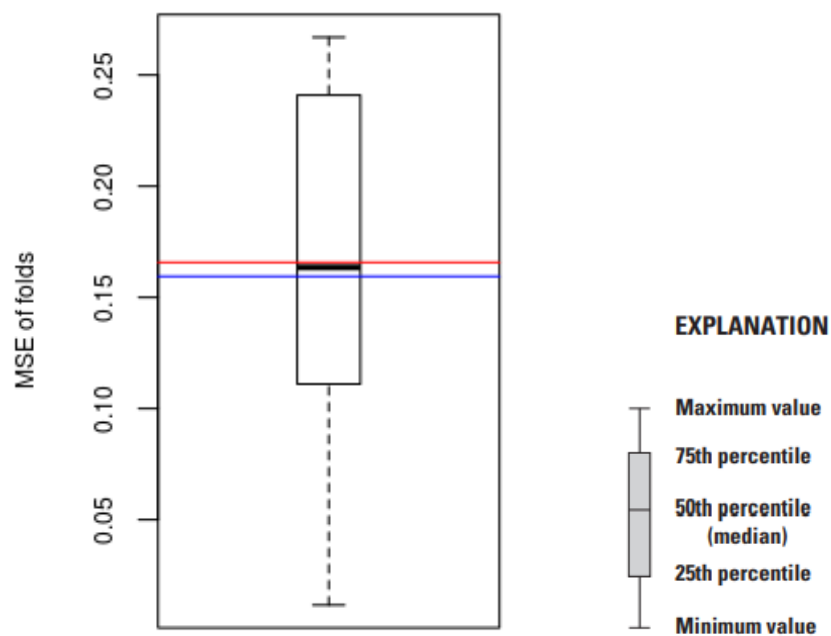




Cross Validation



Minimum mean squared error (MSE) of folds: 0.0116
Mean MSE of folds: 0.1590
Median MSE of folds: 0.1630
Maximum MSE of folds: 0.2670
(Mean MSE of folds) / (Model MSE): 0.9620



Red line - Model MSE

Blue line - Mean MSE of folds

Model-Calibration Dataset

	Date	LogSSC	LogQ	SSC	Q	Computed LogSSC	Computed SSC	Residual	Normal Quantiles	Censored Values
0										
1	2009-08-12	2.05	2.75	112	560	2.14	198	-0.0929	-0.294	--
2	2009-08-27	3.33	3.56	2120	3620	2.79	881	0.536	1.39	--
3	2009-09-09	3.19	3.7	1560	4960	2.9	1130	0.294	0.7	--
4	2009-10-09	2.22	3.1	166	1260	2.42	379	-0.204	-0.59	--
5	2009-10-29	3.06	3.19	1150	1560	2.5	449	0.563	1.52	--
6	2009-10-30	2.8	3.8	627	6380	2.99	1390	-0.189	-0.487	--
7	2009-11-19	2.11	3.52	128	3290	2.76	816	-0.65	-1.52	--
8	2010-03-09	3.38	3.66	2420	4540	2.87	1060	0.515	1.28	--
9	2010-05-13	3.12	3.71	1310	5140	2.91	1170	0.205	0.487	--
10	2010-06-15	2.84	4.27	691	18600	3.36	3260	-0.519	-1.1	--
11	2010-06-16	2.76	4.26	579	18200	3.35	3200	-0.588	-1.19	--
12	2010-06-10	3.29	4.06	1950	11500	3.19	2210	0.0997	-0.0223	--
13	2010-07-15	2.97	4.02	924	10400	3.16	2040	-0.19	-0.538	--
14	2010-09-16	2.46	2.96	286	922	2.32	295	0.141	0.248	--
15	2010-09-17	3.21	3.56	1610	3610	2.79	879	0.418	1.1	--
16	2010-12-06	1.52	3.01	33	1020	2.35	321	-0.833	-1.9	--
17	2011-03-28	1.83	2.87	68	745	2.24	249	-0.409	-0.951	--
18	2011-04-11	3.21	3.29	1610	1970	2.58	542	0.628	1.9	--
19	2011-06-09	1.79	2.48	62	302	1.93	121	-0.136	-0.389	--

20	2011-10-24	1.43	1.69	27	48.8	1.3	28.2	0.136	0.157	--
21	2011-12-20	2.93	3.33	842	2120	2.6	574	0.321	0.758	--
22	2012-03-01	3.29	3.33	1930	2120	2.6	574	0.682	2.3	--
23	2012-03-22	3.32	3.75	2110	5620	2.94	1250	0.382	0.951	--
24	2012-03-23	3.24	3.98	1750	9600	3.13	1920	0.114	0.112	--
25	2012-09-27	1.87	2.37	74	236	1.84	99.4	0.0268	-0.112	--
26	2013-08-01	2.86	4.12	722	13100	3.24	2470	-0.379	-0.883	--
27	2013-08-01	3.2	4.12	1580	13200	3.24	2480	-0.0401	-0.248	--
28	2013-08-15	2.67	4.18	469	15200	3.29	2770	-0.617	-1.28	--
29	2013-10-23	1.52	2.25	33	178	1.74	79.3	-0.226	-0.644	--
30	2014-03-17	1.15	2.07	14	119	1.6	57.3	-0.457	-1.02	--
31	2014-05-27	2.82	3.11	667	1300	2.44	389	0.389	1.02	--
32	2014-06-06	3.63	3.82	4230	6630	3	1430	0.626	1.68	--
33	2014-10-30	1.72	1.9	52	78.7	1.46	41.3	0.255	0.59	--
34	2015-01-28	1.18	1.96	15	91.8	1.51	46.7	-0.338	-0.819	--
35	2015-04-20	3.09	3.46	1230	2870	2.71	732	0.38	0.883	--
36	2015-05-18	3.09	4.27	1220	18500	3.36	3250	-0.27	-0.758	--
37	2015-06-16	3.16	4.16	1440	14400	3.27	2650	-0.111	-0.341	--
38	2015-09-24	1.77	2.11	59	128	1.63	61	0.141	0.202	--
39	2015-12-01	2.18	2.97	151	929	2.32	297	-0.139	-0.437	--
40	2016-01-14	2.06	2.68	114	482	2.09	176	-0.0329	-0.202	--
41	2016-02-25	1.23	2.4	17	251	1.86	104	-0.634	-1.39	--
42	2016-04-19	2.49	3.09	310	1240	2.42	374	0.0739	-0.067	--
43	2016-04-21	3.37	3.94	2370	8660	3.09	1770	0.282	0.644	--
44	2016-04-27	3.3	4.22	2000	16600	3.32	2970	-0.0173	-0.157	--
45	2016-09-09	3.09	3.75	1230	5650	2.94	1260	0.145	0.341	--
46	2016-10-07	2.71	3.32	515	2100	2.6	570	0.111	0.0223	--
47	2017-01-26	1.28	2.66	19	461	2.07	170	-0.796	-1.68	--
48	2017-03-29	3.26	4.01	1830	10200	3.15	2010	0.114	0.067	--
49	2017-10-05	1.65	1.94	45	87	1.5	44.7	0.158	0.389	--
50	2018-01-29	1.26	1.93	18	85	1.49	43.9	-0.232	-0.7	--
51	2018-06-26	1.79	1.9	61	78.7	1.46	41.3	0.324	0.819	--
52	2018-08-20	2.79	3.27	615	1880	2.56	521	0.227	0.538	--
53	2018-09-06	3.55	3.88	3570	7520	3.04	1580	0.509	1.19	--
54	2018-10-10	2.49	4.48	312	30400	3.53	4830	-1.03	-2.3	--
55	2019-02-24	3.22	3.92	1660	8240	3.08	1700	0.145	0.294	--
56	2019-03-14	3.43	4.11	2680	13000	3.23	2440	0.195	0.437	--

Definitions

Adj R^2 : Adjusted coefficient of determination

BCF: Bias correction factor

DFFITS: Studentized difference in fits

Log: logarithm base 10

MSE: Mean squared error

MSPE: Model standard percentage error

R²: Coefficient of determination

RMSE: Root mean square error

SSC: Suspended-sediment concentration, in milligrams per liter (80154)

Q: Streamflow, mean daily, in cubic feet per second (00060)

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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